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**McWherter**

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(54) **DIGITAL 3D INFRARED SLIT LAMP WITH PUPIL MEASUREMENT**

USPC ..... 351/205, 206, 209-212, 214, 221, 243, 351/246

See application file for complete search history.

(71) Applicant: **Ian W McWherter**, Louisville, KY (US)

(56) **References Cited**

(72) Inventor: **Ian W McWherter**, Louisville, KY (US)

U.S. PATENT DOCUMENTS

(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 204 days.

5,841,509 A \* 11/1998 Harooni ..... A61B 3/132 351/221

6,050,688 A 4/2000 Grinblat

6,089,716 A \* 7/2000 Lashkari ..... A61B 3/1241 351/205

6,319,273 B1 11/2001 Chen et al.

7,083,281 B2 8/2006 Yogesan et al.

2003/0020871 A1 \* 1/2003 Niven ..... A61B 3/117 351/200

2013/0235346 A1 \* 9/2013 Huang ..... A61B 3/152 351/208

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FOREIGN PATENT DOCUMENTS

CA 2377162 \* 2/2001 ..... A61B 3/10

OTHER PUBLICATIONS

Expert Rev Dermatol. Apr. 1, 2013; 8(2): 177-184. doi:10.1586/edm.13.15., The role of dynamic infrared imaging in melanoma diagnosis, Cila Herman.

\* cited by examiner

Primary Examiner — Jie Lei

(74) Attorney, Agent, or Firm — Joel Douglas

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**A61B 3/12** (2006.01)

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(2013.01); **A61B 3/15** (2013.01); **A61B 3/107**

(2013.01); **A61B 3/12** (2013.01)

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A61B 3/135; A61B 3/15; A61B 3/00;

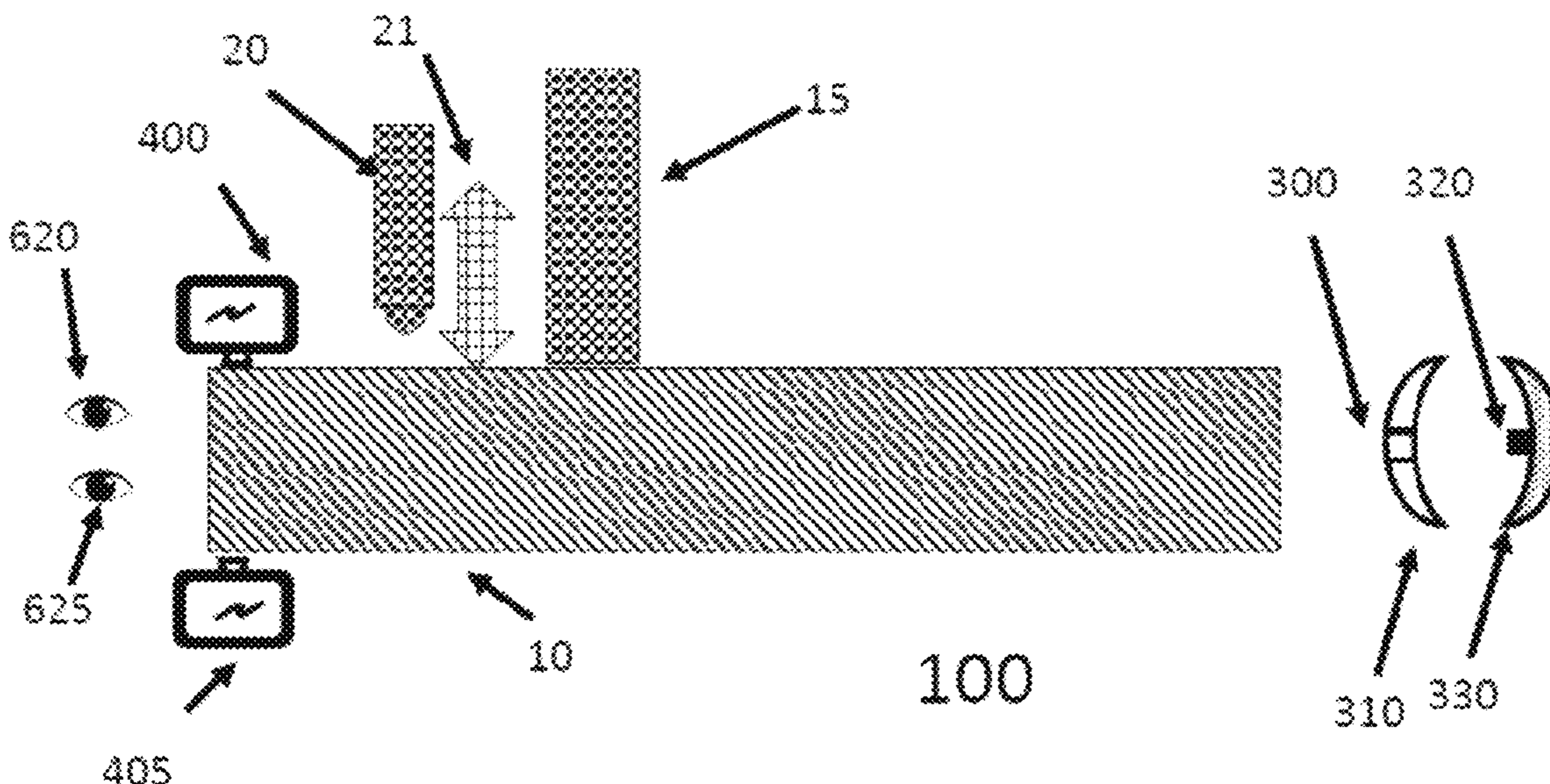
A61B 1/06; A61B 1/0684; A61B 1/0653;

A61B 1/227

(57) **ABSTRACT**

A device and method of ophthalmic diagnosis of lesions on retina utilizing a slit lamp apparatus with a pupil reader and at least one visible LED and one Infrared LED to detect a lesion on the retina of an eye.

**14 Claims, 9 Drawing Sheets**



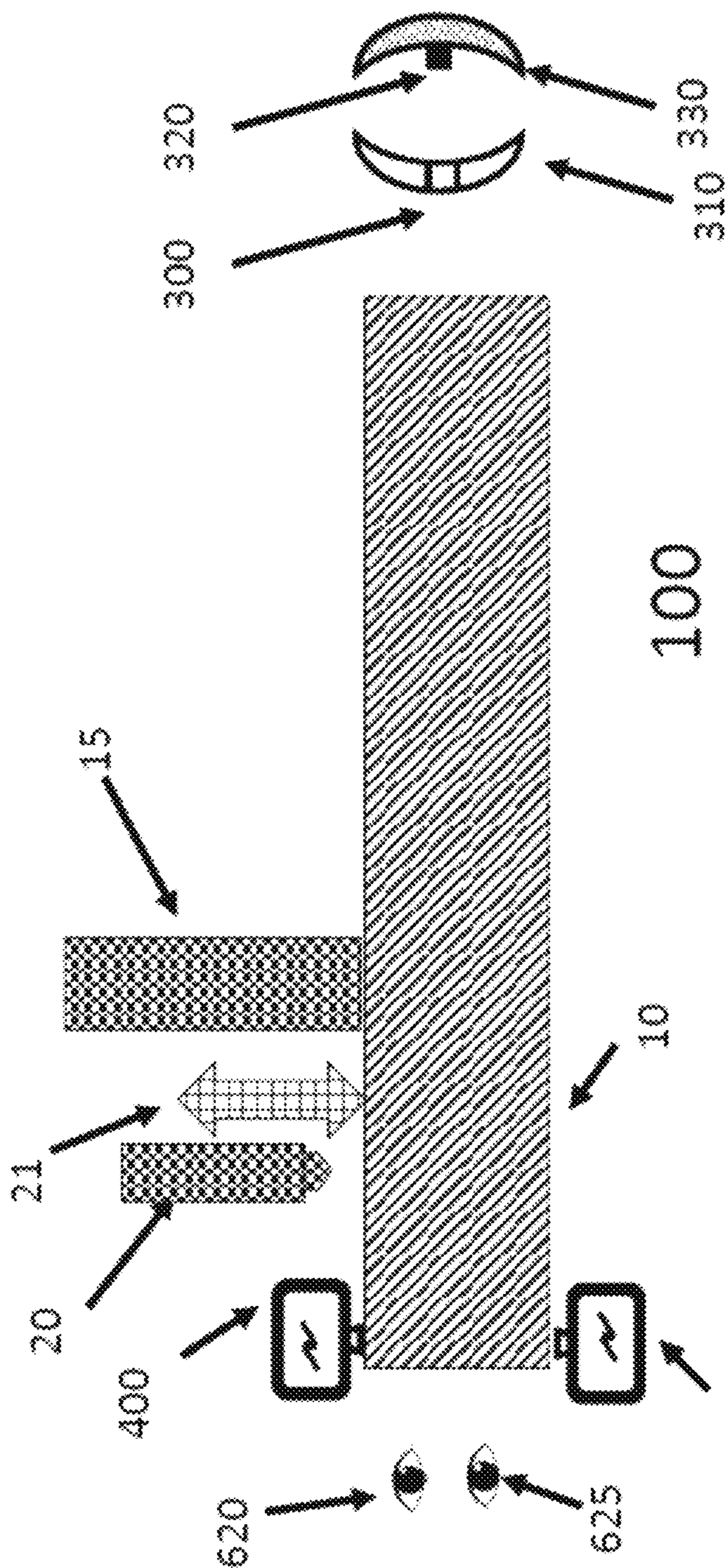
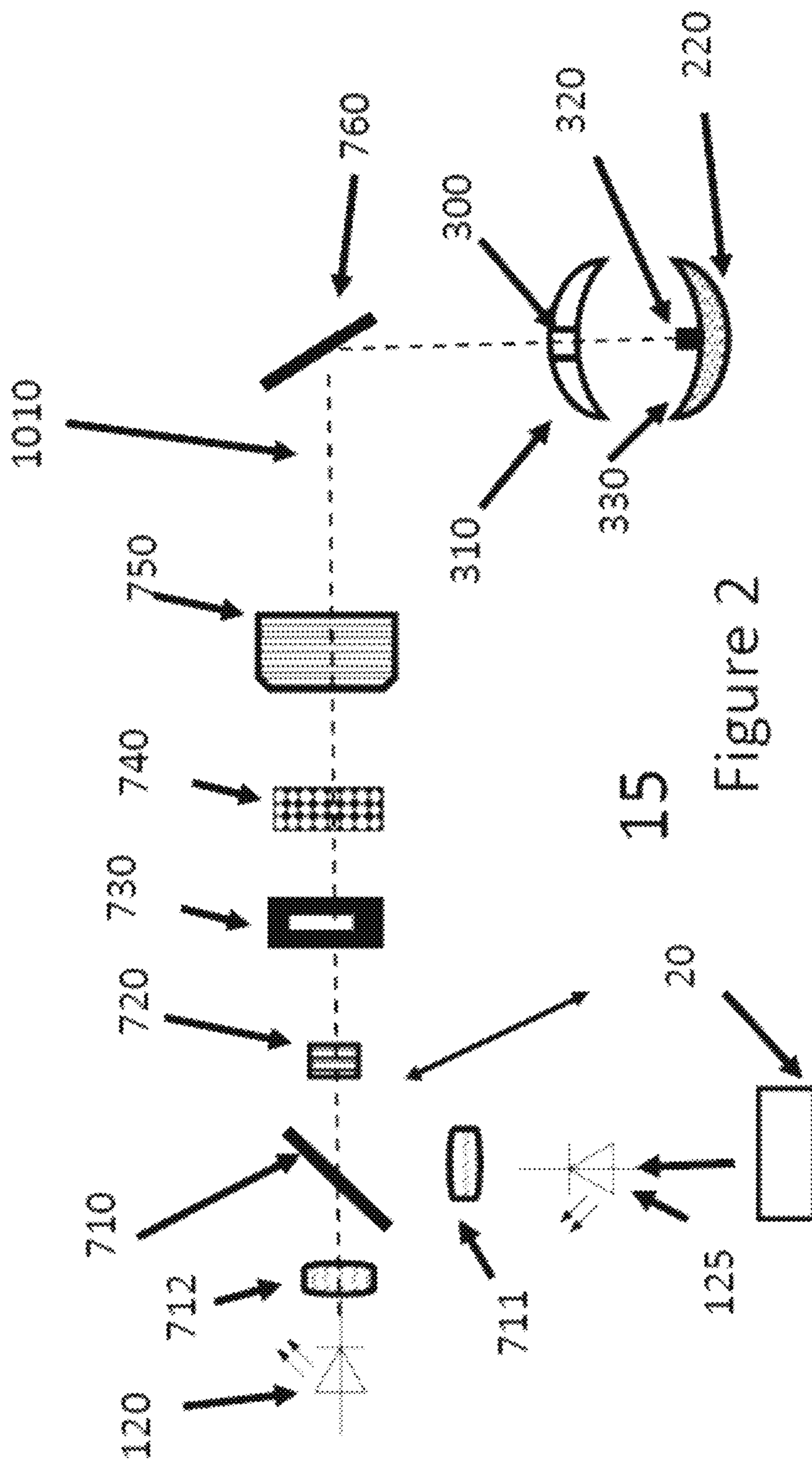


Figure 1



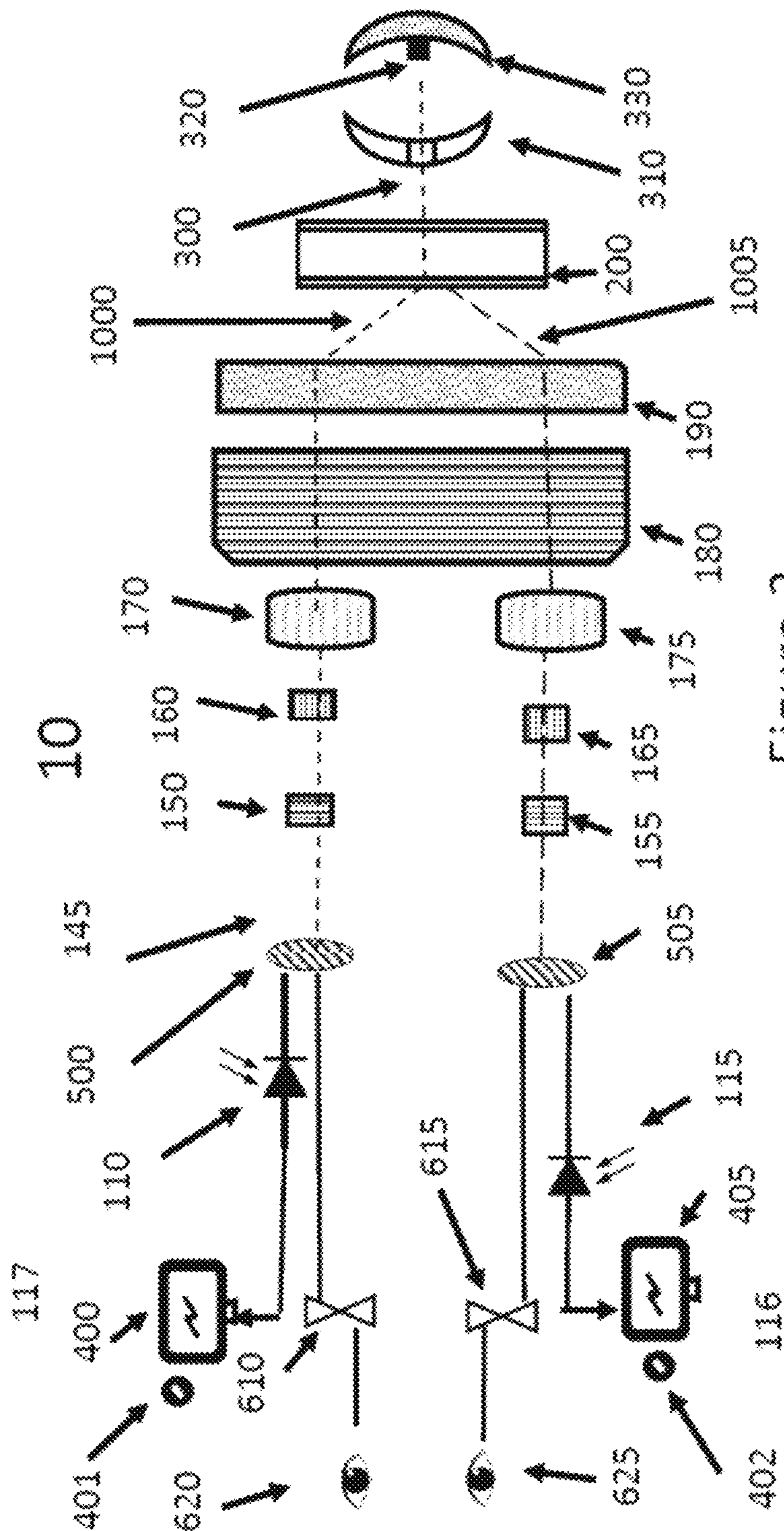


Figure 3

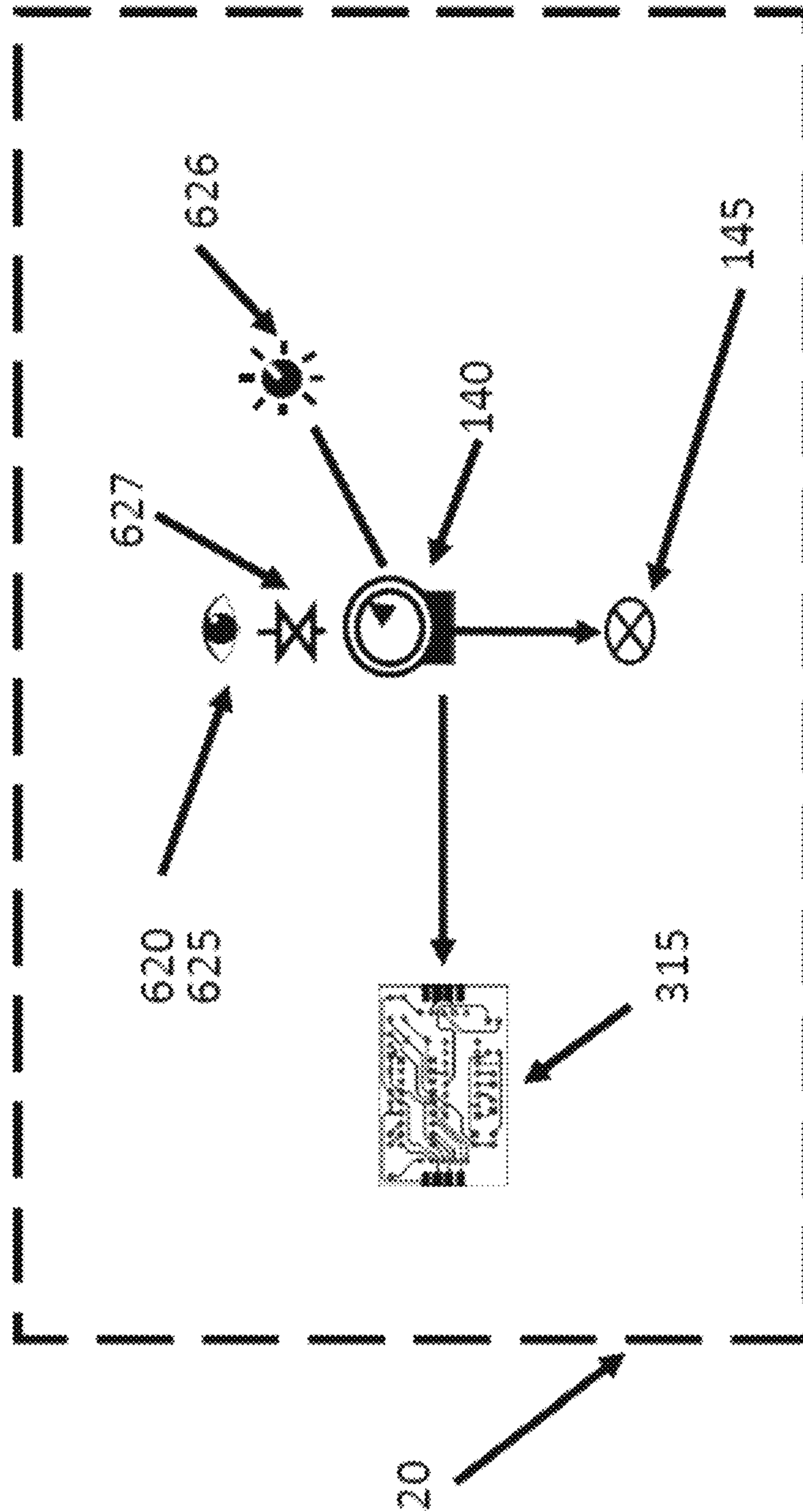


Figure 4

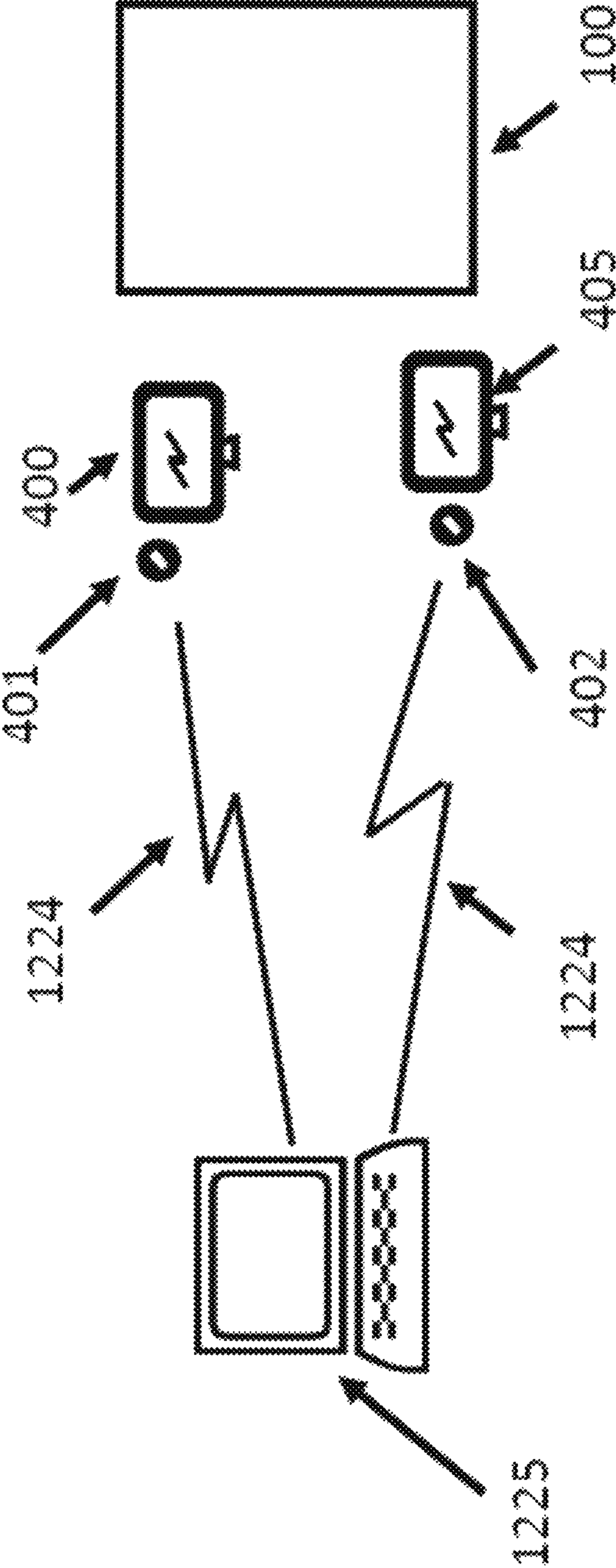


Figure 5

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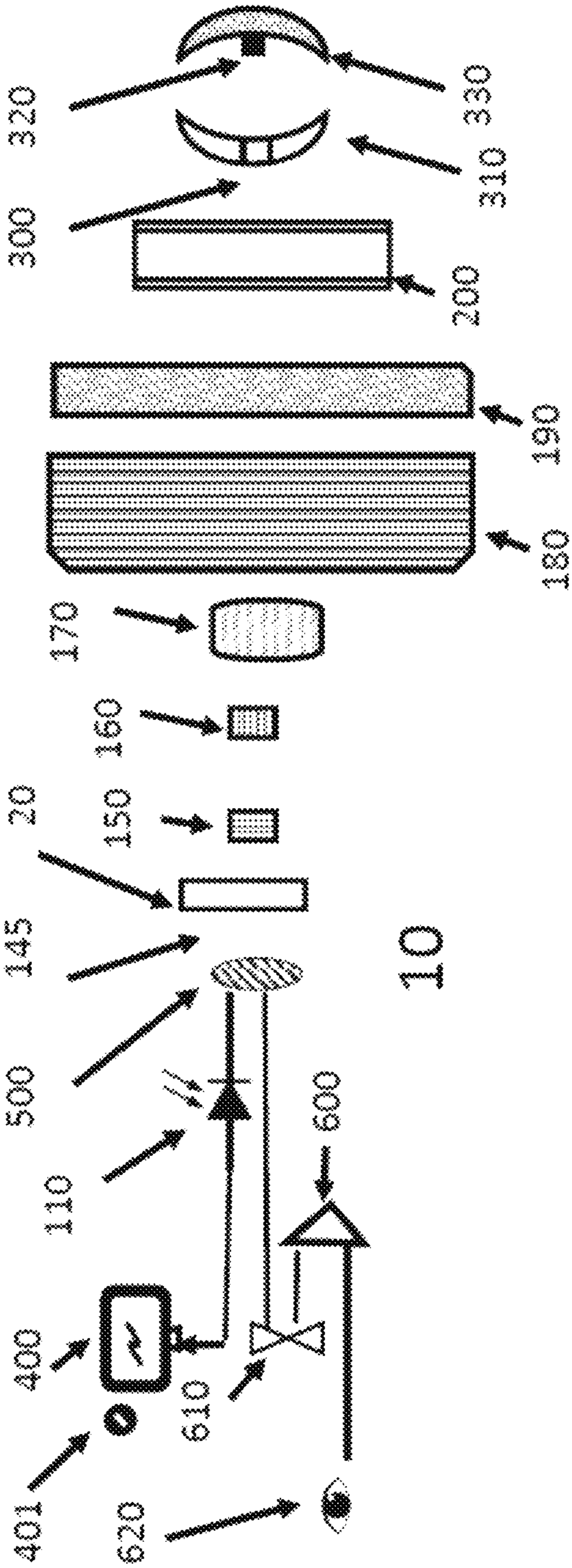


Figure 6

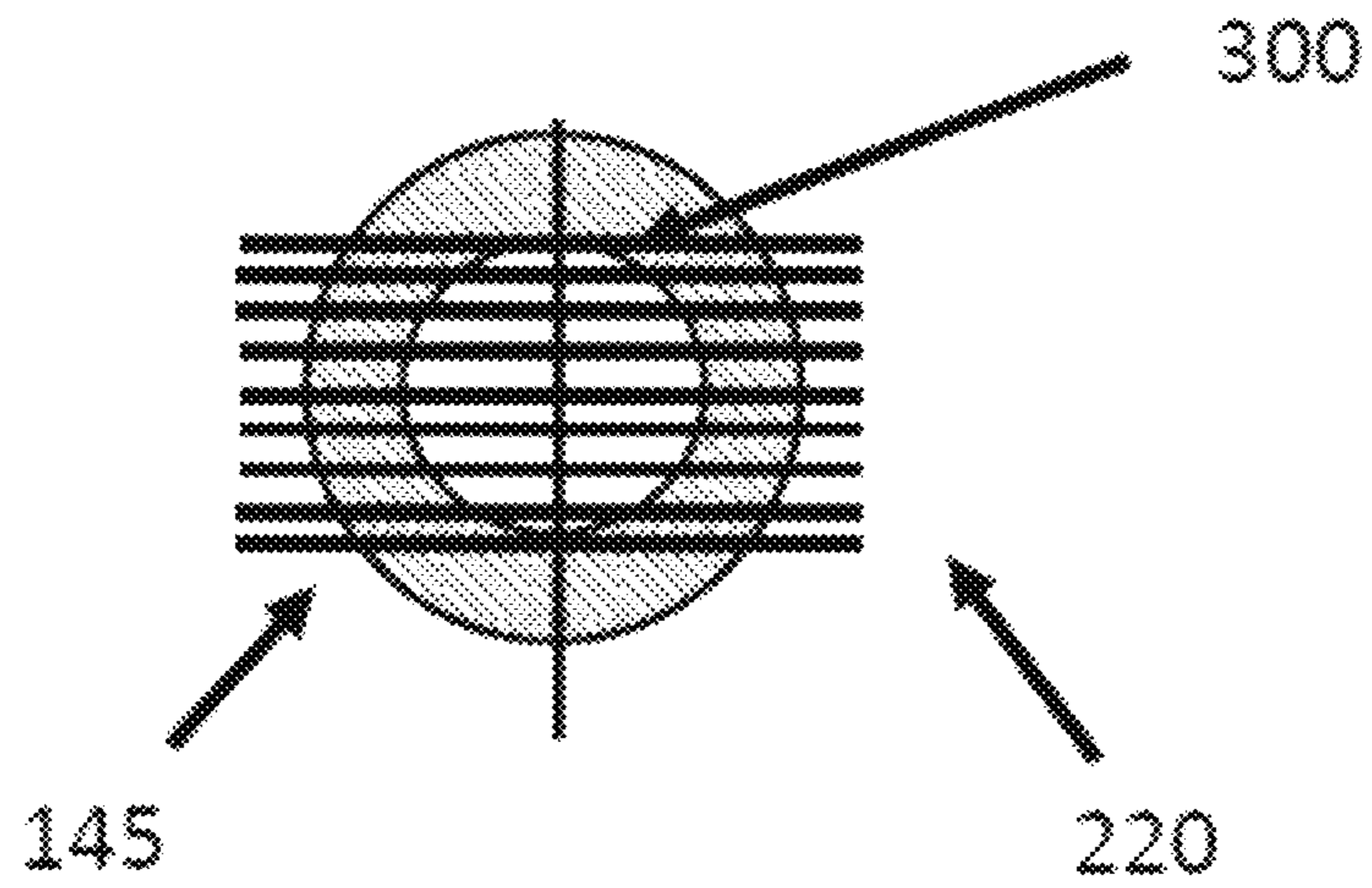


Figure 7



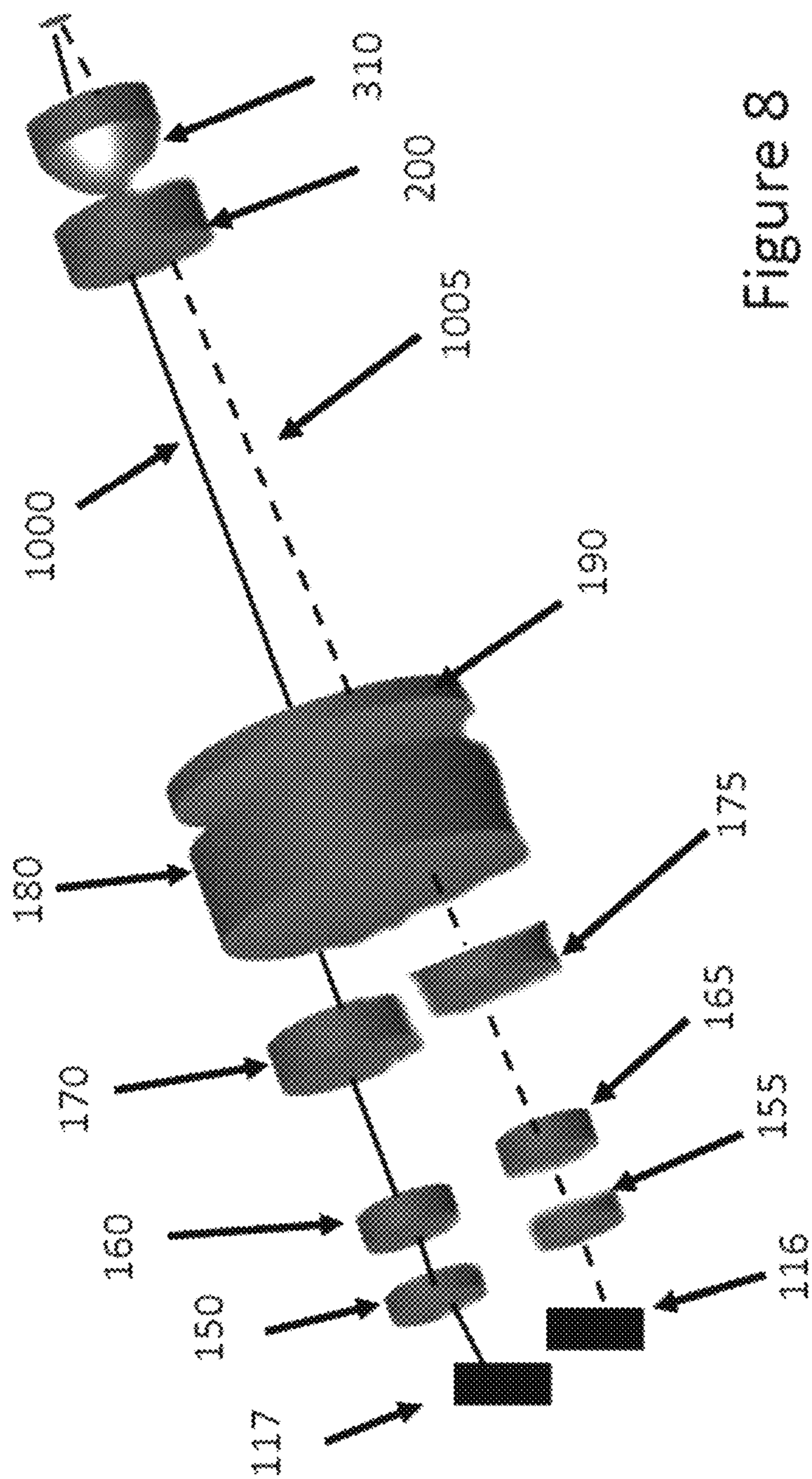


Figure 8

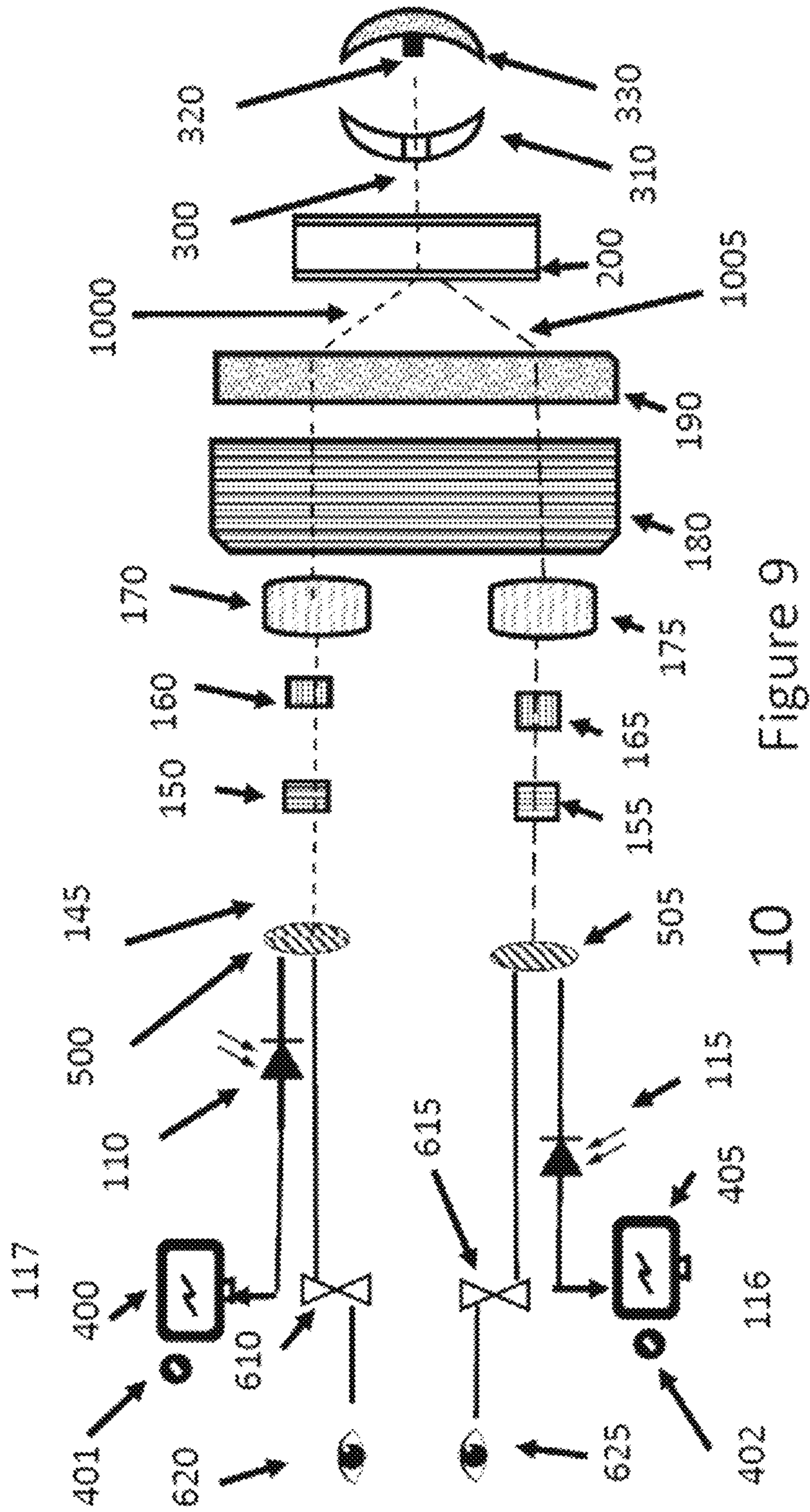


Figure 9

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**DIGITAL 3D INFRARED SLIT LAMP WITH PUPIL MEASUREMENT****CROSS-REFERENCE TO RELATED APPLICATION**

This application claims priority from U.S. provisional patent application Ser. No. 62/636,867, filed Mar. 1, 2018 entitled Digital 3D slit lamp which is hereby incorporated by reference herein for all purposes.

**STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT**

The research for the Patent "Digital 3D Infrared Slit lamp with Pupil measurement" was not funded by any federally sponsored research or development.

**DESCRIPTION****Field of Disclosure**

This invention relates generally in one aspect to slit-lamps for use in ophthalmic diagnosis and treatment. In another aspect, the invention is concerned with the application of a slit-lamp to measure metabolic activity with IR light.

**Background of the Invention**

The cornea of the eye is essential for good vision. It is the outermost tissue of the eye and functions like a window allowing the entry of light into the eye. An established branch of ophthalmic medicine is the examination of optically reflected corneal images as a diagnostic tool in the identification of trachomatous scarring, cataracts, injuries or bacterial and viral infections. These images are captured using slit-lamps to provide a narrow beam of light of elongated slit-shaped cross-section which is projected onto the cornea to study the surface characteristics. The reflected image is in effect an optical section of the anterior part of the eye including the cornea, the anterior chamber, the iris or the lens and the anterior part of the vitreous. For identifying some conditions, the ophthalmologist seeks to identify changes in the reflected image over time.

Commercial slit-lamp instruments are generally available and they are used as described to inspect the cornea for various disease states. Additionally, using condensing lenses the retina, a layer of tissue in the back of the eye that collects lights, similar to the film of a camera, can also be evaluated using a slit lamp. It is also known that by changing the wavelength of light away from the visible light spectrum and to an infrared light source—a wavelength of light that is poorly absorbed by the retina and eyes photoreceptors, a patient's comfort can be dramatically increased allowing the full field of the patient's fundus to be examined all at one time. Secondly, infrared measuring systems can identify between healthy tissue and a disease state. However, to adequately illuminate the retina the amount of infrared light needs to be tuned to the size of the patient's pupil. This allows the intensity of the infrared light used to be optimized to safely display the greatest thermal imaging response possible between healthy tissue and a disease.

It is an object of this invention to provide a slit-lamp capable of utilizing both visible light and longer wavelength infrared light and allow the physician to alternate the source to get the optimal reading when viewing the cornea and retina of the patient.

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It is an object of the invention to provide a slit-lamp capable of measuring critical eye features so that the intensity of the illumination is optimized for the infrared detection cycle and provides an added safety measure to prevent phototoxicity of retina.

It is an object of the invention to provide a slit-lamp capable producing 3D digital images.

**BRIEF SUMMARY OF THE INVENTION**

In a first aspect, the invention provides slit-lamp apparatus, including a body. Solid state lamp means and associated optics for generating a, narrow beam of light white light and a narrow beam (or full beam) of infrared light and projecting the beams onto the cornea, lens or retina of a patient's eye for reflection by structures of the eye, when the slit-lamp apparatus is position in front of the eye. The solid-state lamp means to detect a reflection of the narrow beam of white light by structures of the eye and to make an image thereof, which image is, or is processable to provide, a digital record of the reflection. The solid-state lamp means being also capable of generating and detecting a narrow beam, or full beam, infrared light by structures of the eye and to make an image thereof, which image is, or is processable to provide, a digital record of the reflection of both the visible and the infrared images. The infrared light is used by the physician to detect any lesions that are on the lens, cornea, retina by looking at the thermal imaging of the eye structures. Additionally, the infrared light intensity is controlled by initial measurements of the Pupil of the eye to ensure the optimal intensity of infrared light is utilized to detect lesions on the, retina or choroid.

For the visible light a narrow beam is preferable in the form of an elongated slit-shaped cross-section. This is due to limitations from reflections from ocular structures but also due to the amount of light that a patient can comfortably tolerate during an examination. For the infrared light source full beam is preferable to illuminate the cornea or retina to achieve a full field view all in one image. The physician is capable of viewing the image from the cornea or retina with a slit lamp and digital imaging.

The solid-state lamp means is conveniently two or more light emitting diodes. At least one LED capable of emitting visible light and another LED being capable of emitting infrared light. Additional, wavelength of lights can also be included in the slit lamp to enhance the evaluation of specific ocular tissue.

Advantageously, the solid-state lamp means consists of a pair of solid state lamps which have separate controls for activation and intensity.

The associated optics preferably includes a series of lens arranged generally for focusing a light beam emitted towards retina on a patient's eye as a narrow beam of light.

Preferably, the associated optics include structure defining a slit aligned with and disposed to receive light from said elongated light means, to define a light beam of elongated cross-section.

Preferably, there are a pair of said solid state lamp means and associated optics selectively operable for generating and projecting respective said narrow or full beams of light onto the corneas or retina of the patients left and right eyes respectively.

The means to detect the reflection and to make a digital record of the reflection of the narrow beam of light may be a CCD camera but is preferably a digital camera sensor and associated optics.

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The slit-lamp apparatus preferably further includes means to transmit the digital record for storage, and for review and diagnosis subsequently and/or at a remote location. Such means to transmit the digital record may comprise WIFI, Bluetooth, USB connection to a local computer for storage and, in one or more embodiments, for online transmission to the remote location.

Preferably, the portable slit-lamp apparatus further includes means mounted to the body for providing background illumination of the cornea and retina. This illumination is preferably of adjustable brightness.

A method is preferably provided as part of the control means for both the visible and infrared light sources to adjust the width, height and orientation of the narrow beam of light.

In a second aspect, the invention provides a method of ophthalmic diagnosis utilizing a slit lamp apparatus according to the first aspect of the invention including: taking a measurement of the Pupil of the patients eye, calculating or selecting an illumination factor based on the Pupil dimension, adjusting the intensity of the light source based on the Pupil size, projecting a narrow or full beam of light, generated by said solid state lamp means and associated optics, onto the cornea or retina of a patient's eye; detecting, with said detecting means, a reflection of said beam of light by structures of the eye, displaying a 3 dimensional image in real time on a display means, making a digital record of the reflection and viewing in real time, and transmitting said digital record to a second location remote from the first for additional review and diagnosis.

Preferably the display means is a comprised of two separate displays that provide a 3D image through 2 separate oculars to achieve stereopsis.

Preferably, said narrow beam is of elongated slit-shaped cross-section.

Preferably, the method further includes reviewing the digital record of the reflections as a 3-dimensional digital image in real time and performing an ophthalmic diagnosis on the basis of the record. Advantageously, the digital record is reproduced as a viewable image/film to assist the physician with the diagnosis.

The transmission of the digital record of the reflection may be by transport of a memory device, but is preferably via the internet or other network means from a local computer at the first location to a remote storage device or computer in a remote site.

#### BRIEF DESCRIPTION OF THE DRAWINGS

A further understanding of the nature and advantages of embodiments may be realized by reference to the remaining portions of the specification and the drawings, in which like reference numerals are used to refer to similar components. When reference is made to a reference numeral without specification to an existing sub-label, it is intended to refer to all such multiple similar components.

The invention will now be further described by way of example only, with reference to the accompanying drawings, in which:

FIG. 1 is a diagram showing the system components of the invention of dual light slit-lamp apparatus and digital monitoring device according to an embodiment of the invention without light paths.

FIG. 2 is a diagram of the light source module showing the light path to the eye.

FIG. 3 is a diagram showing the infrared light path from the patient's retina, through the indirect lens, into the stereo

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slit lamp, ending at the infrared detector arrays for a slit lamp with infrared two detector arrays.

FIG. 4 is a diagram showing the infrared tuning interface system.

FIG. 5 is a diagram of the invention used with an associated computer system.

FIG. 6 is a diagram showing the infrared light path from the patient's retinas, through the indirect lens, into the mono slit lamp, ending at the infrared detector array for an slit lamp with infrared one detector array.

FIG. 7 is a diagram showing the patients pupil and the caliper for measuring the pupil.

FIG. 8 is a simplified light path diagram of the optics module.

FIG. 9 shows the light path of the optics module without Caliper module in the light path

#### DETAILED DESCRIPTION OF INVENTION

While various aspects and features of certain embodiments have been summarized above, the following detailed description illustrates a few exemplary embodiments in further detail to enable one skilled in the art to practice such embodiments. The described examples are provided for illustrative purposes and are not intended to limit the scope of the invention.

In the following description, for the purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the described embodiments. It will be apparent to one skilled in the art, however, that other embodiments of the present invention may be practiced without some of these specific details. Several embodiments are described herein, and while various features are ascribed to different embodiments, it should be appreciated that the features described with respect to one embodiment may be incorporated with other embodiments as well. By the same token, however, no single feature or features of any described embodiment should be considered essential to every embodiment of the invention, as other embodiments of the invention may omit such features.

In this application the use of the singular includes the plural unless specifically stated otherwise, and use of the terms "and" and "or" is equivalent to "and/or," also referred to as "non-exclusive or" unless otherwise indicated. Moreover, the use of the term "including," as well as other forms, such as "includes" and "included," should be considered non-exclusive. Also, terms such as "element" or "component" encompass both elements and components comprising one unit and elements and components that comprise more than one unit, unless specifically stated otherwise.

Numerical values for dimensions, volumes and masses in this specification are shown in U.S. customary units. Teaspoons and tablespoons are taken as their volumetric equivalent units in the Avoirdupois system. Since accelerations and forces are not relevant to the description or use of the invention, U.S. customary units of weight such as ounces and pounds shall indicate their customary equivalent masses as stationary objects.

The use of the term physician when used is synonymous with practitioner, nurse, healthcare professional, optician, optometrist, ophthalmologist, technician and person.

The use of the term monitor when used is synonymous with viewing display.

The invention is particularly useful because if not only is applicable for diagnosing lesions on the retina of the eye but can be used to evaluate all the ocular tissue, mostly the

cornea, retina, and lens. Therefore, the term ocular tissue can be equally substituted with the term retina, cornea and lens.

The shape and diameter of the human eye after puberty is relatively consistent from patient to patient. The average diameter is of the Pupil is from 1.3 to 8 mm. <https://sites.google.com/site/waxfin/eyedimensions> The current practice is to dilate the eye to get the widest aperture. However, this causes discomfort to the patient. Additionally, it has been found that infrared imaging is effective in the diagnosis of melanoma. Published in final edited form as: Expert Rev Dermatol. 2013 Apr. 1; 8(2): 177-184. doi: 10.1586/edm.13.15. This article documented that results from a clinical study suggest that the temperature of cancerous lesions is higher during the first 45-60 seconds of thermal recovery than the temperature of benign pigmented lesions. This small temperature difference can be measured by modern infrared cameras and serve as an indicator for melanoma in modern quantitative melanoma detectors. Therefore, since cancer of the retina is difficult to identify accurately the invention couples the use of thermo-imaging technology with an enhanced ophthalmic slit light device to create a means of inspecting and diagnosing lesions on the retina of the eye. The invention is particularly useful because if not only is applicable for diagnosing lesions on the retina of the eye but can be used to evaluate all the ocular tissue, mostly the cornea, retina, and lens.

The instant invention can best be summarized as a device and method of ophthalmic diagnosis of lesions on retina **330** (the term ocular tissue can be equally substituted with the term cornea and lens) utilizing a slit lamp apparatus **100** as shown in FIGS. **1,2,3,4,5** and **7** with at least one visible LED **120** and one Infrared LED **125** to detect a lesion on the retina **330** of an eye comprising: a) measuring the diameter of the Pupil **300** using a caliper **145** and the light from the infrared LED **125**, b) adjusting the intensity of an infrared LED **125** based on the diameter of the Pupil **300**, c) applying the infrared light from the infrared LED **125** to the retina **330** of an eye, d) detecting the heat signature of the cells on the retina/ocular tissue **330** using an infrared detector arrays **110** and **115**, e) creating a 3D digital image on viewing displays/monitors **400** and **405** from the heat signature on the infrared detector arrays **110** and **115** creating a digital image on viewing displays/monitors **400** and **405**, such that the image is viewed through 2 separate oculars to achieve stereopsis f) analyzing the digital image by comparing the difference of the detected heat signature and flagging the higher thermal response for further investigation. g) transmitting said digital image to a computer **1225** for storage, and for review and diagnosis.

The illustrated slit-lamp apparatus **100** shown graphically in FIGS. **1** and **8** comprises light source **15** optics module **10**, Caliper module **20** which is optionally able to be engage or disengage, viewing displays/digital monitors **400** and **405** which form two separate displays that provide a 3D image through 2 separate oculars to achieve stereopsis, a digital link **1224** and computer **1225**, and a program to capture the images from said digital monitors. As shown in FIGS. **2** and **4** light source **15** which contains infrared tuning interface **20**, which has a Caliper **145** in communication with optics **627**. Caliper **145** is also in communication with Pupil reader **140** which uses the infrared light from LED **125** to illuminate the eye **220**. The slit-lamp apparatus uses the infrared light from LED **125** to measure the diameter of Pupil **300**. The measurement of the diameter of pupil **300** provides the system with the relative opening provided by the Pupil with respect to the eye which permits the controller **315** that is in communication with pupil reader **140** to adjust the intensity

of infrared LED **125** so that the intensity of infrared LED **125** provides the best detection parameters to detect a lesion **320** on retina **330**. The term retina **330** is used here to provide a tangible organ within the overall structure of the eye. However, the invention is applicable for all ocular tissues and the term retina can be equally substituted with the term ocular tissue, cornea and lens. FIGS. **3** and **8** shows the light paths **1000** and **1005**.

As shown in FIGS. **1, 2, 3** and **4** the physician can operate the slit lamp with either visible or infrared light. First reviewing the visible light operation and light path **1010** shown in FIG. **2**, the operator first engages the visible light from LED **120** which enters condenser lens **712** and then beam splitter **710**. It then enters focusing lens **720** and slit mask **730**. It should be noted that the slit mask **730** can also be configured with a means to adjust the width of beam of light from LED **120** or LED **125**. The visible light from LED **120** then enters the color filter **740** and the projection lens filter **750**. The light proceeds mirror **760** and onto to eye **220** passing through and illuminating the retina **330**. The light from the infrared LED **120** is then reflected to the viewing display/monitors **400** and **405**, which form two separate displays that provide a 3D image through 2 separate oculars to achieve stereopsis, or are visually observed by the operator using separate oculars using eyes **620** or **625** using the necessary protective eyewear. As shown in FIGS. **3** and **4** the light reflected off retina **330** to get to the viewing display/monitors **400** and **405** or are visually observed by the operator using eyes **620** or **625** must first pass through most distal lens indirect lens **200** which splits the reflected light into light path **1000** and **1005** then the respective focusing and combining optics module formed from Lens **190** and **180**. The light then passes through the zoom lens module which consist of lenses **175, 170, 160, 165, 155, 150**. When the light exits the most proximal lens pair and **150** and **155** it enters the splitter **500** or **505** which splits the light paths **1000** and **1005** respectively so that it can take two different paths. The first path the light is transmitted to the detection array assembly **117** comprising of detector array **110** and viewing display/monitor **400** or detection array assembly **116** comprising of detector arrays **110** and **115** and viewing display/monitor **405**. The physician can view the images on viewing displays/monitors **400** and **405** which form two separate displays that provide a 3D image through 2 separate oculars to achieve stereopsis.

If the physician wants to inspect the ocular tissue **310** using infrared light the physician must first measure the pupil to determine the correct intensity settings for the infrared light LED **125**. To do this the operator first engages the Caliper module **20**. Caliper module **20** is preferably engaged by slide **21** by sliding Caliper module **20** into optics module **10**. However, the Caliper module **20** could be installed in a non-moveable embodiment if the optics were arranged so that the light would not be obstructed by the Caliper **145**. Once the Caliper module **20** is in place the physician then engages the infrared light from LED **125** which transmits the infrared light so that it enters condenser lens **711** and then beam splitter **710**. After entering the beam splitter **710** the infrared light is on light path **1010**. The infrared light then enters focusing lens **720** and slit mask **730**. It should be noted that the slit mask **730** can also be configured with a means to adjust the width of beam of light from LED **120** or LED **125**. The infrared light from LED **125** then enters the color filter **740** and the projection lens filter **750**. The light proceeds mirror **760** and onto to eye **220** passing through and illuminating the retina **330**. The infrared light from LED **125** is then reflected off retina **330** in the

direction of the viewing display/monitor **400** and **405**. Once the light is reflected off retina **330** the infrared light must first pass through most distal lens indirect lens **200** where it is split into infrared light path **1000** and **1005**. The infrared light then travels through focusing and combining optics module formed from Lens **190** and **180**. The infrared light then passes through the zoom lens module which consist of lenses **175**, **170**, **160,165**, **155**, **150**. When the light exits the most proximal lens pair and **150** and **155** it enters Caliper module **20**. The operator uses the Caliper module **20** as shown in FIGS. **1**, **4** and **7** to measure the pupil diameter which uses Caliper **145**, pupil reader **140**, optics **627**. The operator accomplishes this by measuring the pupil diameter by viewing the pupil with either eye **620** or **625** using optics **627** and using the necessary protective eyewear and using Caliper **145** to determine the diameter of the pupil. The operator then adjusts tuning control **626** to provide the pupil diameter to infrared LED controller **315** which adjust the intensity of the power driving infrared LED **125**. Alternatively, Pupil reader **140** can be designed so that it automatically takes the pupil reading by finding the two most distal points of the interior dimension of the pupil and then by pass tuning control **626** and sets the pupil parameter automatically without intervention from the physician. As the reader is aware the infrared radiation extends from the nominal red edge of the visible spectrum at 700 nanometers (nm) to 1 millimeter (mm). Preferably, the infrared wavelength of the inventions LED **125** is 940~950 nm. However, from initial testing different wavelengths may increase the ability of the invention to identify lesions on the retina. As shown in FIG. **7** when the invention is used without an automated Pupil reader **140** the patients eye **220** and Pupil **300** is seen with the caliper **145** displayed over the Pupil. The physician counts the indicator marks and each indicator mark is equal to 1 mm of Pupil exposure. The physician would set the tuning control **626** to 9 for 9 MM which would reduce the intensity of the infrared light due to the increase area of light entering the eye through Pupil **300** and making contact with the on retina **330**. Preferably, a 9 setting on tuning control **626** is equivalent to a 4 percent reduction in intensity delivered to the LED **125** by infrared LED controller **315**. Also, preferably, each mm reduction in diameter of the pupil as measured by the Caliper **145** represents an additional 0.376% in intensity delivered to the LED **125** by infrared LED controller **315**. Therefore, an 8 mm diameter pupil would result in a 3.624% decrease in the intensity delivered to the LED **125** by infrared LED controller **315** and a 1 mm diameter pupil would result in full intensity of the LED **125** being applied to the retina **330**. This can be automated by integrating the necessary controls into pupil reader **140** such that the pupil reader **140** automatically takes the pupil reading by finding the two most distal points of the interior dimension of the pupil and then by passing tuning control **626** and to set the pupil parameter automatically without intervention from the physician. The change of intensity to the LED **125** is achieved by integrating pulse width modulation into the control circuit for the infrared LED controller **315**. With pulse width modulation, less power is wasted because the drive transistors utilized to achieve the pulse width modulation are either on or off, and when on they have a very low resistance. The circuit needs have a resistor to limit the current when turned on. The design can also incorporate an optional DC to DC converter to generate the correct drive voltage from the input voltage. The required frequency is preferable in the 1 kHz or higher range to limit visible flickering.

Once the intensity for the infrared LED **125** has been adjusted the physician must first disengage the Caliper module **20** by slide **21**. See FIG. **9** for the light path without Caliper module **20** in the light path. The next step is to turn on infrared LED **125** and insure that the visible light LED **120** is off. To make this more automated an interlock system can be implemented that would not allow the visible LED **120** to be on when infrared LED **125** is on. For the operator to see the lesion **320** the infrared light from LED **125** must be applied to the retina **330** or other ocular tissue **310** and therefore must take the following path to the retina. The light from infrared LED **125** enters condenser lens **711** and then beam splitter **710**. It then enters focusing lens **720** and slit mask **730**. The visible light from LED **120** then enters the color filter **740** and the projection lens filter **750**. The light proceeds to mirror **760** and to patient's eye **220** passing through Pupil **300** and illuminating retina **330**. The light from the infrared LED **125** is then reflected to the viewing display/monitor **400** and **405** which form two separate displays that provide a 3D image through 2 separate oculars to achieve stereopsis, or are visually observed by the operator using eyes **620** or **625** using the necessary protective eyewear, this path also provides 2 separate oculars to achieve stereopsis. As shown in FIGS. **2** and **3** the light reflected off retina **330** to get to the viewing display/monitor **400** and **405** or are visually observed by the operator using eyes **620** or **625** must first pass through most distal lens indirect lens **200** then the focusing and combining optics module formed from Lens **190** and **180**. The light then passes through the zoom lens module which consist of lenses **175**, **170**, **160,165**, **155**, **150**. The light exits the most proximal lens pair and **150** and **155** and since the Caliper module **20** is disengaged from the light path the light enters the splitter **500** or **505** which splits the light so that it can take two different paths. The first path the light is transmitted through double porroprisms **610** and double porroprisms **615** respectively and image is visible through 2 separate oculars to achieve stereopsis. The second path the light is transmitted to the infrared detection array assembly **117** comprising of infrared detector array **110** and viewing display/monitor **400** or detection array assembly **116** comprising of detector arrays **115** and viewing display/monitor **405**. Viewing display/monitors **400** and **405** form two separate displays that provide a 3D image through 2 separate oculars to achieve stereopsis. The infrared detector arrays **110** and **115** is preferably, a Hamamatsu G11478-256WB which has proven to perform well when integrated into the invention. However, many different sensors could be utilized and the sensor selected being dependent on the electronics utilized to detect and process the signal. Alternatively, the detection array can be a CCD camera and associated optics adapted for thermal imaging. The viewing displays/monitors **400** and **405** provide the physician the ability to look at the infrared image of the retina or other ocular tissue to identify areas which have a higher heat signature and therefore identify the areas of concern which can then be evaluated by traditional techniques. The viewing displays/monitors **400** and **405** form two separate displays that provide a 3D image through 2 separate oculars to achieve stereopsis. The invention can utilize a number of different monitors which are capable of receiving and processing the infrared information from the infrared detector arrays **110** and **115**. The utility of the invention is based on the findings that the temperature of cancerous lesions is higher during the first 45-60 seconds of thermal recovery when subjected to infrared radiation than the temperature of benign lesions. This small temperature difference can be

measured and serves as an indicator for cancer in the cells of the retina and other ocular tissue. Therefore, by detecting the heat signature of the cells on the retina and comparing the difference of the detected heat signature and flagging the higher thermal response the physician can determine which cells need to be further evaluated and the difference in readings serves as an indicator that the cells may be cancer. The system could also be automated to provide an algorithm that analyzes the heat detected from the ocular tissue and then provide a summary 3-dimensional view of the ocular tissue being examined.

The preferred embodiment of the invention has two parallel optic module light paths and digital monitors. However, the invention in an alternative embodiment could have one digital monitor and corresponding light path. The single light path embodiment is represented in FIG. 6 and for the operator to see the lesion 320 the infrared light from LED 125 must be applied to the retina and therefore must take the similar path as the two-light path embodiment and must first pass through most distal lens indirect lens 200 then the focusing and combining optics module formed from Lens 190 and 180. The light then passes through the zoom lens module which consist of lenses 170, 160 and 150. When the light exits the most proximal lens 150 it enters the splitter 500 which splits the light so that it can take two different paths. The first path the light is transmitted to the infrared detection array assembly 117 comprising of infrared detector array 110 and viewing display/monitor 400. The viewing display/monitor 400 can provide the physician the ability to look at the infrared image of the retina to identify areas which have a higher heat signature and therefore identify the areas of concern which can then be evaluated by traditional techniques. By detecting the heat signature of the cells on the retina the physician can determine which cells need to be further evaluated and the difference in readings serves as an indicator for cancer in the cells of the retina.

It should be noted that the images on viewing displays/monitors 400 and 405 of the Slit-lamp of the invention may be at a fixed angle as illustrated, or mounted for pivotal adjustment to different angles. Magnification may also be variable.

The camera image is viewed in real time on a rear-facing viewing displays/monitors 400 and 405. The viewing displays/monitors 400 and 405 in the preferred embodiment are adjustable of an angular orientation. When it is desired to capture and store an image, as shown in FIG. 5 the physician triggers image capture by activating either button 401 or 402 and the captured image is transmitted by a transmission means as a digital record to a local computer 1225. The transmission means being selected from the Bluetooth, WIFI, USB connection or a cable link 1224. The local computer 1225 may also be configured such that it is a remote device in another room or office or building.

When the physician of the slit lamp presses button 401 or 402, the software program residing on the computer 1225 detects the signals and grab images and stores them on the computer. Therefore, a particular image or video clip can be selected for saving on file in the computer. In an alternative embodiment, the instrument may store digital image records on a memory card that can be downloaded to the computer.

Alternatively, the LEDs 120 and 125 also can comprises one or more light emitting diodes to form an LED array.

It will be appreciated that the illustrated instrument has the great practical advantage in that the capture slit-lamp images can be stored in digital format in a computer hard disk or other storage device for transfer to another location for subsequent diagnosis by ophthalmologists or other

skilled professionals. In accordance with a preferred aspect of the invention, however, the digital record of the images may be transmitted online, via the internet or other network means, to the other location for review and diagnosis. The diagnosis may then be transmitted or forwarded back, e.g. as an online response to the forwarder of the image.

While certain features and aspects have been described with respect to exemplary embodiments, one skilled in the art will recognize that numerous modifications are possible. Further, while various methods and processes described herein may be described with respect to particular structural and/or functional components for ease of description, methods provided by various embodiments are not limited to any particular structural and/or functional architecture.

Hence, while various embodiments are described with or without certain features for ease of description and to illustrate exemplary aspects of those embodiments, the various components and/or features described herein with respect to a particular embodiment can be substituted, added, and/or subtracted from among other described embodiments, unless the context dictates otherwise. Consequently, although several exemplary embodiments are described above, it will be appreciated that the invention is intended to cover all modifications and equivalents within the scope of the following claims.

I claim:

1. A slit-lamp apparatus consisting of a light source module with intensity modulation module, optics module, Caliper module for determining the dimension of a patients pupil and the illumination intensity and area of the illuminated spot on said patient's retina, Digital monitors, a digital link, a computer and a program on said computer in communication with said light source module, said Caliper module measuring said patient's pupil and the intensity and area of the illuminated spot on said patient's retina and said Caliper module, said digital monitors and said computer and said program on said computer adjusting the intensity light source module based on the intensity and area of the illuminated spot on said patient's retina and said Digital monitors captures the images of a patient's ocular tissue and said Digital monitor using said images of a patient's ocular tissue creates a 3-dimensional digital image.

2. The slit-lamp apparatus of claim 1, wherein said light source module comprises of: a) a visible light LED and condenser lens, b) an infrared LED and condenser lens, c) a beam splitter, d) a focusing lens, e) a slit mask, f) a color filter, g) a projection lens, h) a mirror to turn the light 90 degrees.

3. The slit-lamp apparatus of claim 1, wherein the physician using said Caliper module measures said patients pupil and said Caliper module measures the outer dimension of said pupil and the illumination intensity and area of the illuminated spot on said patient's retina, and transfers the outer dimension of said pupil and said illumination intensity and area of the illuminated spot on said patient's retina to said computer and a program and said computer and a program uses said outer dimension of said pupil to set the intensity of said infrared LED in said light source module and said Digital monitors; a) detects the heat signature of the cells, on said ocular tissue using an infrared detection array, b) creates a 3-dimensional digital image on viewing display from said heat signature on said infrared detection array, c) analyzing the said digital image by comparing the difference of the detected heat signature of the cells on the retina and said physician investigating areas of said digital image with higher thermal response, d) transmitting said digital image

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on said viewing displays to a computer for storage using a transmission means, and for review and diagnosis.

4. The slit-lamp apparatus of claim 1, wherein said optics module is in communication with said Caliper module and said Digital monitors.

5 5. The slit-lamp apparatus of claim 1, wherein said optics module comprises of: a) an indirect lens distal from said Digital monitors, b) a focusing lens, c) a combining optics module, d) a zoom lens module, e) a splitter lens, f) an at least one infrared detection array assembly.

6. The slit-lamp apparatus of claim 1, wherein said Caliper module comprises of: a) a Caliper to measure the Pupil diameter of an eye, b) a Pupil reader, capable of measuring the diameter of the patient's pupil, c) an infrared LED controller in communication with a tuning control device to adjust the intensity of the power to said infrared LED.

7. A Pupil reader of claim 6, wherein the pupil of the patient eye is automatically measured.

8. A Pupil reader of claim 6, wherein the pupil of the patient eye is measured by the Physician.

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9. The slit-lamp apparatus of claim 1, wherein said digital monitors are in communication with said computer by a communication link and said communication link consisting of Bluetooth, WIFI, USB connection and a cable link.

10 10. The slip-lamp apparatus of claim 9, wherein said digital monitors are in communication with said computer by a communication link and said communication link consisting of Bluetooth, WIFI USB connection and a cable link.

11. The slit-lamp apparatus of claim 1, wherein said computer contains a program to receive images from said digital onitors.

12. The slit-lamp apparatus according to claim 1, wherein said infrared LED comprises one or more light emitting diodes.

15 13. The slit-lamp apparatus according to claim 1, wherein said visible light LED comprises one or more light emitting diodes.

20 14. The slit-lamp apparatus according to claim 1, wherein said Digital monitors is a CCD camera and associated optics adapted for thermal imaging.

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